



Short Communication

An evaluation of different soil washing solutions for remediating arsenic-contaminated soils



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HIGHLIGHTS

- H₃PO₄, NaOH and EDTA can effectively remove arsenic from a heavily contaminated soil.
- Soil properties were partially changed after washing.
- Wheat grew best in NaOH-treated soil sample.

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ABSTRACT

Soil washing is a promising way to remediate arsenic-contaminated soils. Most research has mostly focused on seeking efficient extractants for removing arsenic, but not concerned with any changes in soil properties when using this technique. In this study, the removal of arsenic from a heavily contaminated soil employing different washing solutions including H₃PO₄, NaOH and dithionite in EDTA was conducted. Subsequently, the changes in soil physicochemical properties and phytotoxicity of each washing technique were evaluated. After washing with 2 M H₃PO₄, 2 M NaOH or 0.1 M dithionite in 0.1 M EDTA, the soil samples' arsenic content met the clean-up levels stipulated in China's environmental regulations. H₃PO₄ washing decreased soil pH, Ca, Mg, Al, Fe, and Mn concentrations but increased TN and TP contents. NaOH washing increased soil pH but decreased soil TOC, TN and TP contents. Dithionite in EDTA washing reduced soil TOC, Ca, Mg, Al, Fe, Mn and TP contents. A drastic color change was observed when the soil sample was washed with H₃PO₄ or 0.1 M dithionite in 0.1 M EDTA. After adjusting the soil pH to neutral, wheat planted in the soil sample washed by NaOH evidenced the best growth of all three treated soil samples. These results will help with selecting the best washing solution when remediating arsenic-contaminated soils in future engineering applications.

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1. Introduction

Arsenic has attracted much concern due to its highly toxic and carcinogenic properties which are dangerous to human beings, animals, and plants. The main anthropogenic sources contributing to arsenic contamination in soils include mining, smelting, agricultural use of pesticides and the disposal of industrial wastes (Mahimairaja et al., 2005; Liao et al., 2005; Chen et al., 2016). In China, a number of arsenic polluted soils have been reported, and the arsenic concentrations in some soils are up to 1217 mg/kg (Liao

et al., 2005; Liu et al., 2005; Wei et al., 2009). This has been as high as 243 times larger than worldwide arsenic background in soil (5 mg/kg) (WHO, 2001) and 41 times the arsenic allowance in soil in China (30 mg/kg, National Standard GB15618-1995). Subsequently this represents a serious threat to human health and the environment.

To remediate arsenic-contaminated soils, solidification/stabilization (Tyrovolá and Nikolaidis, 2009; Yoon et al., 2010), soil washing (Abumaizar and Smith, 1999; Elgh-Dalgren et al., 2009; Sierra et al., 2010, 2011; Gusiati, 2014; Cao et al., 2016), electrokinetic remediation (Mao et al., 2015) and phytoremediation (Ye et al., 2011; Abioye and Uttam, 2016) have been commonly utilized. Of these techniques, soil washing is an effective way to remediate arsenic contaminated soil because it can permanently

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remove arsenic from soil (Dermont et al., 2008). The washing solution is a key factor in the successful application of soil washing technique. Several washing solutions, including NaOH, H₃PO₄, and the combination of dithionite and disodium ethylenediaminetetraacetate dihydrate (EDTA), have been proven to effectively extract arsenic from contaminated soils (Jang et al., 2005; Jho et al., 2015; Kim et al., 2015). However, most research only focused on seeking efficient washing solutions for arsenic removal, but not on any changes in soil properties when using this technique. Documenting the changes in soil properties is equally important in the remediation of a certain contaminated soil.

In this study, arsenic removal from contaminated soil utilizing different washing solutions was conducted. Subsequently, the changes in soil physicochemical properties and phytotoxicity of each washing technique were evaluated. The results obtained in this study are expected to provide some insights for remediating arsenic-contaminated soils in future engineering applications.

2. Materials and methods

2.1. Soil sampling

Arsenic-contaminated soil samples were collected from farmland near an old smelter site in Shimen, Hunan province, in China. For comparison, the background soil sample was collected from nearby farmland. Soil samples were taken from a 0–40 cm layer and air-dried at a room temperature of 20 °C. The soil samples were then sieved through a 2 mm mesh and thoroughly mixed. The prepared soil samples were stored before sample characterization and soil washing tests. The concentrations of arsenic, Al, Fe, Mn, Mg and Ca in soil samples were analyzed via inductively coupled plasma mass spectrometry (ICP-MS, Agilent Technology, 7500 Series) following aqua regia digestion. Arsenic concentrations in contaminated soil and background soil were determined to be 165.5 mg/kg and 13.0 mg/kg.

2.2. Soil washing procedures

A range of NaOH (0.1–5 M), H₃PO₄ (0.1 M–5 M), and 0.1 M dithionite in EDTA (0.05 M–0.2 M) concentrations were initially

used to determine the optimal extractant concentrations for arsenic removal. According to previous studies (Im et al., 2015; Jho et al., 2015), 20 g soil sample was put in a 200 mL flask and then 100 mL of reagent solution was slowly added to achieve a ratio of reagent solutions (mL) to soil mass (g) of 5. The suspension was mixed at 20 ± 0.5 °C in a shaker at 300 rpm for 24 h. Following that, two hundred grams of each soil sample were mixed with the optimal extractant concentrations in a 2 L flask at the soil to solution ratio of 1:5, which were shaken using the same procedure. The soil slurries were then centrifuged at 5000 g for 30 min and the supernatant was passed through a 0.45 μm filter (Sartorius) for metal analysis. The soil pellets were rinsed with deionized water for 30 min by shaking on a reciprocal mixer and then dried after discarding the supernatant.

2.3. Soil sample characterization

Soil samples were characterized before and after soil washing as follows: Soil pH was measured with a soil/solution ratio of 1:1 (w/v), using a 0.01 M CaCl₂ solution (McLean, 1982). Total organic carbon (TOC) content was analyzed according to the Walkley–Black wet oxidation method (Nelson and Sommers, 1982). The cation exchange capacity (CEC) at neutral pH was determined using the ammonium acetate method with 5 g of soil (Thomas, 1982). Particle size distribution was determined according to the approach proposed by Gee and Bauder (1986). Total nitrogen (TN), total phosphorus (TP) and total potassium (TK) were measured according to the Methods of Soil Analysis (Page et al., 1982). Soil colors were determined by using a Munsell soil color chart. The dissolved Al, Fe, Mn, Mg and Ca concentrations in the extraction solutions were measured via ICP-MS.

2.4. Wheat pot experiment

To minimize the destruction of soil properties, the soil samples treated by H₃PO₄ or NaOH were adjusted to neutral (pH = 7.0) by 0.1 M NaOH or 0.1 M HCl, respectively. The soil samples were blended with deionized water with a soil/solution ratio of 1:1 (w/v). Neutralizer was added dropwise to the solution and stirred with a glass rod. The pH of soil samples was adjusted every 24 h to keep

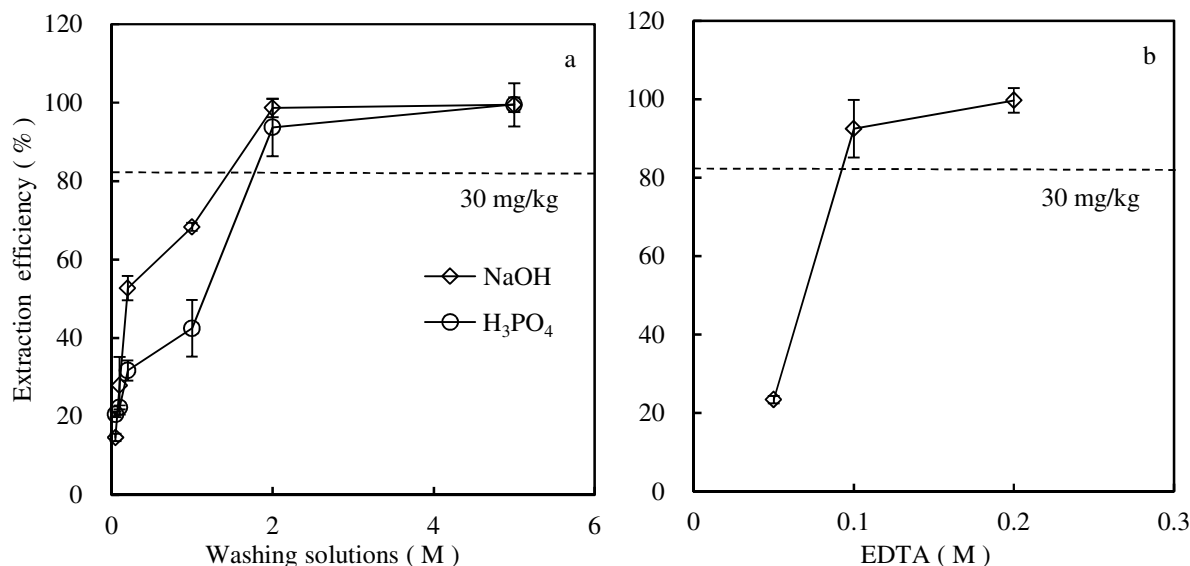


Fig. 1. Extraction of arsenic from soil with different concentrations of (a) NaOH, H₃PO₄ or (b) 0.1 M dithionite in EDTA. Dash line represents environmental quality standard for soils in China (30 mg/kg).

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